# 4 Compliance Through Quality Construction

The *Standards* require quality design and construction of HVAC systems and air distribution systems. They also offer compliance credit for the construction of less leaky building envelopes. With the 2001 *Standards*, testing of ducts, refrigerant charge, and airflow was added to the prescriptive requirements (Package D) and is assumed as part of the standard design in performance calculations. Many of the compliance credit options require installer diagnostic testing and certification, and independent diagnostic testing and field verification by a certified Home Energy Rater. This chapter is organized in the following sections.

- Duct Efficiency
- Infiltration & Ventilation
- Refrigerant Charge and Air Flow Testing
- Diagnostics and Field Verification
- Procedures for HVAC System Design and Installation

## 4.1 Duct Efficiency

### 4.1.1 Overview

HVAC duct efficiency is a very important feature in energy efficient buildings. The prescriptive requirements require that ducts be sealed and tested in all climates. This requirement was added with the 2001 *Standards*; previously it was a compliance option. Duct efficiency is impacted by the following parameters

1. Duct location (attic, crawlspace, basement, inside conditioned space, or other).
2. Condition of the unconditioned space, e.g., does the attic have radiant barriers
3. Duct insulation
4. Duct surface area
5. Air leakage of the duct system
6. Design of the duct system to ACCA Manual D

In performance calculations, duct efficiency can be calculated in one of two ways: (1) default input assumptions or (2) diagnostic measurement values (see also Section 4.4). The computer program will use default assumptions for the proposed design when the user does not intend to make improvements in duct efficiency. For low-rise residential buildings there is a compliance penalty if the ducts are not sealed and tested.

Methods for conducting diagnostic testing and field verification for duct efficiency improvements are described in detail in *Appendix F* of the *Alternative Calculation Method Approval Manual,* which is repeated in the *Residential Energy Conservation Manual* as Appendix J.

Also, the duct connections and leaks shall not be sealed with cloth back rubber adhesive tapes (i.e., duct tapes) unless such tape is used in combination with mastic and draw-bands. This requirement must be specified in the HERS Required Verification listings on the CF-1R and the CF-4R.

When more than one HVAC system serves the building or dwelling, the duct efficiency is determined for each system based on the improvements made to each duct system, and a conditioned floor area-weighted average of the efficiencies of each separate system is determined.

### 4.1.2 Duct Location

The location of ducts has a significant effect on the efficiency of distributing heated or cooled air. Therefore, the location of ducts affects the way the program models the overall efficiency of space conditioning equipment. Ducts are typically installed in attics. This is the location that results in the greatest energy loss. This is the default location for compliance purposes. Ducts located in crawlspaces, basements or in conditioned space can be significantly more efficient and may require HERS rater verification as discussed below. Ducts in other spaces (i.e., not in crawlspaces, basements or in conditioned space; e.g., in garages) are assumed to perform the same as ducts in attics. When compliance credit is taken for improved duct location, the installer must certify on the CF-6R that the ducts are installed in that location.

A default compliance credit for ducts located in crawlspaces or basements may be approved by the local enforcement agency without HERS rater verification. The default assumptions for ducts installed in crawlspaces or basements apply only to buildings with all supply ducts installed in the crawlspace or basement. A duct layout must be included in the plans that show that all of the supply registers are located in the floor. If any story of a building has any supply registers located more than two feet above the floor, the duct location for that story must be modeled as 100% in the attic. The computer program will automatically specify that all supply registers for each story are located in the floor in the *Special Features and Modeling Assumptions* listing to aid the local enforcement agency's inspections.

Compliance credit for ducts in locations other than attics is also available by using the diagnostic duct surface area alternative. This alternative requires HERS rater verification. In this alternative, compliance can be determined by specifying the duct surface area in each location in which the supply ducts are to be installed. With this method, there must be an *ACCA Manual D Design* identifying the duct locations, sizes and airflow to each room as described in Section 4.1.8, and the HERS rater must verify the *ACCA Manual D Design* (which includes airflow to each room) and that the installation matches the design for duct sizes, lengths and surface areas in each location as specified in Section 4.1.6. When using this diagnostic surface area alternative for ducts in crawlspaces (or other locations), there are no limitations on the locations of individual registers as long as they match the design.

The distribution of duct surface areas by location must appear on the *HERS Required Verification* list of a compliance computer program output for verification by an approved HERS rater.

### 4.1.3 Ducts Inside Conditioned Space

Credit is given when most or all of the ducts of a ducted HVAC system are installed inside conditioned space. Credit can be taken for ducts inside the conditioned space for two situations: 1) Less than 12 lineal feet of ducts within unconditioned space; and 2) all ducts (and the air handler) within the conditioned space. The first situation would typically apply to a ducted furnace or heat pump inside a garage with a relatively short duct run from the air handler to the conditioned space.

Compliance credit can also be taken for duct systems where all ducts including the air handler are installed inside conditioned space. Ducted, central gas furnaces installed in this manner will need to have provisions for supplying outdoor air for combustion and combustion product venting without using draft relief openings. These ducts in conditioned space options must be specified on the *HERS Required Verification* list for verification by an approved HERS rater.

Non-central gas furnaces [those listed in Table G-1 of Appendix G in this *Manual*] such as wall furnaces are compared to a *Standard Design* using a non-central gas furnace with no ducts and the minimum allowed efficiency for the type of furnace used in the *Proposed Design*. Similarly, non-central air conditioners [those listed in Table G-3B of Appendix G of this *Manual*] are compared to a similar non-central air conditioner without ducts in the *Standard Design*. Other systems, such as hydronic heating systems with a central heater or boiler and multiple terminal units, are considered central HVAC systems that are compared to a ducted system in the *Standard Design*. Since the hydronic system has no ducts, there is a significant energy credit through the performance method.

### 4.1.4 Ducts in Attics with Radiant Barriers

Installation of a radiant barrier in the attic increases the duct efficiency by lowering attic summer temperatures. Compliance credit for radiant barriers requires listing of the radiant barrier in the *Special Features and Modeling Assumptions* listings to aid the local enforcement agency's inspections. Compliance credit for a radiant barrier does not require HERS rater verification.

### 4.1.5 Duct Insulation

The R-value of duct insulation is specified for ducts in unconditioned space. R-4.2 is a mandatory feature and is the default R-value. Compliance credit can be taken for additional duct insulation. If ducts with multiple R-values are installed, the lowest duct R-value shall be used for the entire duct system. In some cases the space on top of the duct boot is limited and cannot be inspected. For this reason, the insulation R-value within two feet of the boot may be excluded from the determination of the overall system R-value. When the modeled R-value is greater than 4.2, the computer program must report the specified R-value in the *Special Features and Modeling* Assumptions listing to aid the local enforcement agency's inspections. Compliance credit for Increased duct insulation does not require HERS rater verification.

### 4.1.6 Duct Surface Area

The default values for duct surface areas outside of conditioned space are 27% of conditioned floor area (CFA) for supply duct surface area; 5% of CFA for return duct surface area in single story dwellings and 10% of CFA for return duct surface area in dwellings with two or more stories. Compliance credit can be taken for proposed designs with reduced duct surface areas outside of conditioned space. The proposed design can specify field measured reduced supply duct surface area. If compliance credit is taken for reduced supply surface area, the installer must certify the installed surface area on

the CF-6R. Duct surface area shall be calculated from measured duct lengths and nominal diameters to the outside of the duct insulation (for round ducts) or perimeters of the outside of the duct insulation (for rectangular ducts) of each duct run in the building.

Reduced duct surface areas must be shown to preserve adequate airflow to receive duct efficiency credit. Consequently, compliance credit for measured reduced duct surface area can only be taken in conjunction with ducts that are designed to conform to ACCA manual D (including duct layout and design specifications on the plans). The total specified measured surface area and its subcomponent allocation by duct location must be in the *HERS Required Verification* listing, and be verified by a certified HERS rater. Credit for measured reduced duct surface area also requires that the HERS rater verify the consistency of the actual duct system with the ACCA Manual D design as specified in Section 4.1.8 below.

### 4.1.7 Duct Leakage

Prescriptive Packages C and D require that ducts be diagnostically tested to have a leakage of 6% of fan airflow or less. This is a prescriptive requirement that can be traded off only in performance calculations. If duct sealing and diagnostic testing is not planned in performance calculations, then a leakage of 22% of fan airflow must be used in the calculations for the proposed design.

The target duct leakage is determined as a percentage of the fan airflow. Fan airflow is determined as described below.

*Determining Fan Airflow*

With either of the above methods, it is necessary to determine the fan airflow before the leakage can be calculated. Fan airflow can be determined using one of four methods described below:

1. Fan airflow can be based on the cooling capacity of the equipment. With this method the fan airflow is assumed to be 400 cfm/ton times the capacity of the equipment in tons. This is the most common and easiest method to determine fan flow.
2. Fan airflow can be based on the heating capacity of the equipment. In this case the fan airflow is assumed to be 21.7 cfm/(kBtu/h) times the capacity of the heating equipment in thousands of Btu/h. This method is typically used for heating only systems.
3. The fan airflow can be based on floor area. For climates 8 through 15, fan airflow can be assumed to be 0.7 cfm/ft² times the floor area served by the system. For climates 1 through 7 and 16, the fan airflow can be assumed to be 0.5 cfm/ft² times the floor area served. This is the default method used by the approved computer methods.
4. The fan airflow can be measured in the field (see Appendix J for measurement procedures).

In addition to installer leakage testing and certification, the prescriptive requirement for duct sealing requires diagnostic testing and verification by a certified HERS rater. The *HERS Required Verification* listing and the CF-6R must specify the target duct leakage(s) for verification by the HERS rater.

### 4.1.8 ACCA Manual D Design – Duct Layout and System Fan Flow

The default condition assumes that the duct system has not been designed to meet ACCA manual D. Compliance credit can be taken if the duct system is designed to meet ACCA manual D, and a duct layout showing locations and sizes of ducts and placement of registers, engineering calculations, and duct system specifications are in the plans. The plans must specify either the system fan flow determined by the ACCA manual D design or the installation of a thermostatic expansion valve. The installation of a

thermostatic expansion valve must be verifiable through installation of a removable access panel on the cooling coil. The ACCA Manual D design calculations must be submitted with the permit application along with the plans and energy calculations. This submittal does not need to include the specific ACCA Manual D calculation forms, but must include the same information in a format similar to that used in the ACCA Manual D forms so that a reviewer using ACCA Manual D can readily identify the calculations match those identified in ACCA Manual D.

Compliance credit for ACCA manual D design requires diagnostic testing and verification by an approved HERS rater. The system fan flow or the installation of a thermostatic expansion valve must be specified on the *HERS Required Verification* listing. The HERS rater must verify the existence of the ACCA manual D design, specifications and layout, and verify the consistency of the actual HVAC distribution system with the design. This consistency check includes verifying that space-by-space load and supply air calculations were done for each space, that duct runs are no longer than the design, that the ducts are not compressed or constricted, and that duct sizes and insulation R-values match the design. The HERS rater also must either 1) diagnostically test the system fan flow and verify that the fan flow specified by the ACCA manual D design is achieved or 2) remove the access panel and verify the installation of the thermostatic expansion valve.

# 4.2 Infiltration & Ventilation

## 4.2.1 Overview

Infiltration is the unintentional replacement of conditioned air with unconditioned air through leaks or cracks in the building envelope. This is a major component of heating and cooling loads. Ventilation is the intentional replacement of conditioned air with unconditioned air through opening windows or mechanical ventilation. Credit is offered through compliance methods for options that reduce building envelope air leakage.

Ventilation in residential buildings is typically achieved by opening windows either to provide natural ventilation for cooling purposes or to reduce stuffiness or odors. The use of continuous mechanical ventilation provides a greater degree of control of the rate of exchange of conditioned and unconditioned air. Continuous mechanical ventilation can be provided through either supply fans or exhaust fans. Providing **supply** fan ventilation is also a means to avoid building depressurization, which otherwise can lead to backdrafting of combustion appliances in “unusually tight” buildings.

Reduction in building envelope air leakage reduces infiltration and can result in significant energy savings especially in climates with more severe winter and summer conditions. It also can result in improved building comfort, reduced moisture intrusion, and can avoid introduction of air pollutants due to leakage from garages or attics.

## 4.2.2 Indoor Air Quality

ASHRAE Standard 62 *Ventilation for Acceptable Indoor Air Quality* specifies a minimum effective annual air exchange rate. This minimum rate is the combination of infiltration, ventilation through window opening and continuous mechanical ventilation if supplied. For typical California homes infiltration is excessive and the ASHRAE 62 standard is met or exceeded with occasional window opening. As building envelope leakage is reduced, the frequency for when windows need to be opened slightly to relieve stuffiness, remove odors and provide indoor air quality increases.

### 4.2.3 Optimal Building Envelope Leakage

From an energy standpoint there is an optimal level of reduced building envelope air leakage if additional ventilation is provided through opening windows alone. Below that optimal building envelope air leakage, the energy penalty of increased frequency of window opening exceeds the energy savings of the reduction in infiltration. If building envelope leakage is reduced substantially below the optimal energy savings level, a level that the Commission considers to be "unusually tight" per the California Mechanical Code can be reached where it is necessary to provide continuous mechanical supply ventilation.

### 4.2.4 Algorithms

Algorithms approved by the Commission keep track of the combination of infiltration, ventilation through opening windows, and continuous mechanical ventilation, if any, to model conformance with the ASHRAE 62 standard and determine the energy consequences. Approved computer programs can be used to determine optimal building envelope leakage levels that can be specified for compliance purposes.

Approved computer programs use a default building envelope air leakage (expressed in terms of Specific Leakage Area, SLA) for proposed designs when the user does not intend to take compliance credit for building envelope sealing. The default is set at 4.9 SLA. Careful attention to building envelope sealing would result in significantly lower SLA levels.

### 4.2.5 Blower Door Testing

Compliance credit can be taken for reduced building envelope leakage verified through diagnostic blowerdoor testing as specified by ASTM E-779-87, *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*. Users of approved computer programs can determine the compliance credit available for Specific Leakage Area (SLA) levels (or target blowerdoor test results). The program will automatically convert that SLA level to the target $cfm50_H$ required for the blowerdoor testing to achieve the modeled SLA, and specify that target $cfm50_H$ level in the *HERS Required Verification* listing on the CF-1R and C-2R. The installer must do testing to demonstrate that building envelope leakage has been reduced to the target $cfm50_H$ level or lower, and document the blowerdoor test results on the CF-6R. An approved HERS rater must do blowerdoor testing to verify that the target $cfm50_H$ has been achieved (see Section 4.4 for Diagnostics and Field Verification procedures and requirements). Installers and HERS raters should be aware of minimum cfm requirements described in 4.2.6.

### 4.2.6 Mechanical Supply Ventilation Requirements for Unusually Tight Buildings

Compliance software will report in the *HERS Required Verification* section the minimum allowed $cfm50_H$ (corresponding to an SLA of 1.5) unless continuous mechanical **supply** ventilation is installed. This minimum allowed value without continuous mechanical supply ventilation is considered by the Commission to be "unusually tight" per the requirements of the California Mechanical Code.

The *HERS Required Verification* section of the CF-1R must state that when the minimum blowerdoor testing reveals that the $cfm50_H$ is less than the minimum allowed value, corrective action must be taken either to intentionally increase the infiltration or provide for continuous mechanical **supply** ventilation adequate to maintain the residence at a pressure greater than -5 Pascal relative to the outside air pressure with other continuous ventilation fans operating. Blowerdoor testing must be done by both the installer and the HERS rater to verify compliance with these requirements.

The total power consumption of the continuous supply ventilation fans and continuous exhaust fans are required inputs when compliance credit is taken for reduced building envelope leakage and mechanical ventilation is installed.

### 4.2.7 Mechanical Ventilation Requirements for Low Leakage Designs

When the user of compliance programs chooses the proposed design envelope leakage to be below 3.0 SLA, continuous mechanical ventilation (either exhaust or supply ventilation) must be installed. Whenever continuous mechanical ventilation is installed, a minimum capacity of 0.047 cfm per square foot of conditioned floor area is required. This requirement for installation of continuous mechanical ventilation is reported automatically by the program in the *HERS Required Verification* section of the CF-1R and C-2R. The installer and the HERS rater must confirm compliance with these requirements.

When reduced building envelope leakage or continuous mechanical ventilation is specified for compliance, the computer program will automatically include in the *Special Features and Modeling Assumptions* section a statement that the homeowner's manual provided by the builder to the homeowner must include instructions that describe how to use the operable windows or continuous mechanical ventilation for proper ventilation.

The total power consumption of the continuous supply ventilation fans and continuous exhaust fans are required inputs when compliance credit is taken for reduced building envelope leakage and mechanical ventilation is installed.

### 4.2.8 Envelope Leakage Credit for Reduced Duct Leakage

If compliance credit is **not** taken for reduced building envelope air leakage through diagnostic testing, a special "default" compliance credit can be taken for building envelope leakage reduction resulting from reduced duct leakage. To qualify for this credit all requirements for reduced duct leakage described in Section 4.4, including diagnostic testing, must be met. A "default" reduction in Specific Leakage Area of 0.50 is allowed for this credit.

### 4.2.9 Air Retarding Wrap Credit

If compliance credit is **not** taken for reduced building envelope air leakage through diagnostic testing, a special "default" compliance credit can be taken for building envelope leakage reduction resulting from installation of an air retarding wrap (i.e., housewrap). To qualify for the "default" compliance credit, an air retarding wrap must be tested and labeled by the manufacturer to comply with ASTM E1677-95, *Standard Specification for an Air Retarder (AR) Material or System for Low-Rise Framed Building* Walls, and have a minimum perm rating of 10. Insulating sheathing and building paper do not qualify as air retarding wraps.

The air-retarding wrap must be installed per the manufacturer's specifications that must be provided to comply with ASTM E1677-95. In particular, the air-retarding wrap must meet the following installation requirements:

- The air retarding wrap must be applied continuously
- All tears or breaks must be repaired with manufacturer approved tape
- All horizontal seams must be lapped in a shingle-like manner and taped.
- All vertical seams must be lapped.
- All windows and penetrations must be taped or caulked
- The air-retarding wrap must be taped or otherwise sealed at the slab junction

When compliance credit is taken for an air-retarding wrap, the computer program will automatically include the air retarding wrap and the above specifications in the *Special Features and Modeling* Assumptions section of the CF-1R and C-2R to facilitate inspection by the local enforcement agency. Compliance credit for an air-retarding wrap does not require HERS rater verification.

Compliance credit is provided for a "default" reduction in Specific Leakage Area of 0.50.

### 4.2.10 Reduced Duct Leakage in Combination with Air Retarding Wrap

The default credits in Sections 4.2.8 and 4.2.9 may be added when both measures are installed and the criteria in Sections 4.2.8 and 4.2.9 are both met.

## 4.3 Refrigerant Charge and Air Flow Testing

This section describes the procedures for verifying that split system air conditioners have the correct refrigerant charge and that they have adequate airflow across the cooling coils. The prescriptive requirements require this testing if the air conditioner does not have a thermostatic expansion valve (TXV). Appendix L of this *Manual* (also Appendix K of the Residential ACM Approval Manual) describes the procedures in detail, and refrigeration technicians who do the testing should refer to these and other more technical documents. This section is just a summary intended for those who need to know about the procedures but will not be doing the testing.

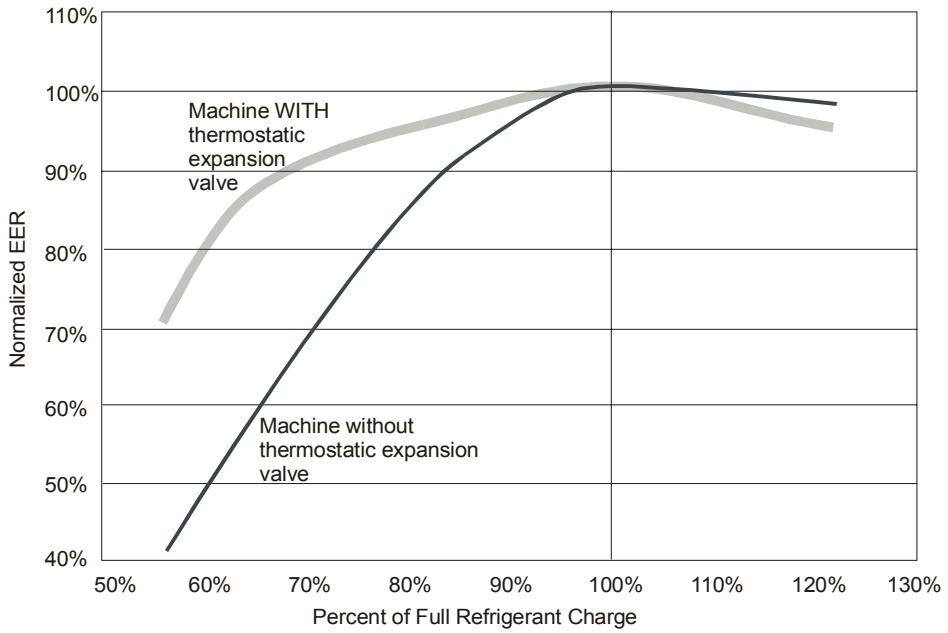
### 4.3.1 Overview

A residential air conditioner is a complicated piece of equipment, and like an automobile, it must be tuned in order to achieve maximum performance and the best energy efficiency. Two important factors are the amount of refrigerant in the system (the charge) and the airflow rate across the evaporator (the cooling coil near the fan). Air conditioner energy efficiency suffers if the refrigerant charge is too low or if the airflow across the coil is not adequate. In addition to a loss of efficiency, excessive refrigerant charge can lead to premature compressor failure while insufficient charge can cause compressors to overheat. Low airflows can lead to ice buildup on the cooling coil and lead to compressor failure. High airflow is not generally a problem.

To help avoid these problems the prescriptive standards require that systems be correctly installed. This section describes the measurements and tests required to verify proper installation. The testing requirement applies only to ducted split system central air conditioners and ducted split system central heat pumps that do not have thermostatic expansion valves (TXVs). If a TXV is installed, refrigerant charge and airflow testing are not necessary. Nor does the testing requirement apply to packaged systems, where the refrigerant charge is verified in the factory. The testing must occur after the HVAC installer has installed and charged the system in accordance with the manufacturer's specifications. For homes with multiple systems, each system must be tested separately.

Figure 4-1 shows how a thermostatic expansion valve can help mitigate the efficiency penalty of a system with too little refrigerant (under charged). As long as the machine has the correct charge (100%), the TXV has no benefit. However, for systems that are undercharged, the efficiency falls off less rapidly if a TXV is installed.

*Figure 4-1– Benefit of Thermostatic Expansion Valve*




Two procedures are described here for testing refrigerant charge and airflow. The first procedure, the Standard Charge and Airflow Measurement procedure (Section 4.3.2), may be done by a HERS rater and applies only when the outdoor temperature is above 55 ºF. The second procedure, the Alternate Charge and Airflow Measurement procedure (Section 4.3.3), must be performed by a refrigeration technician and must be used when the outdoor temperature is below 55 °F.

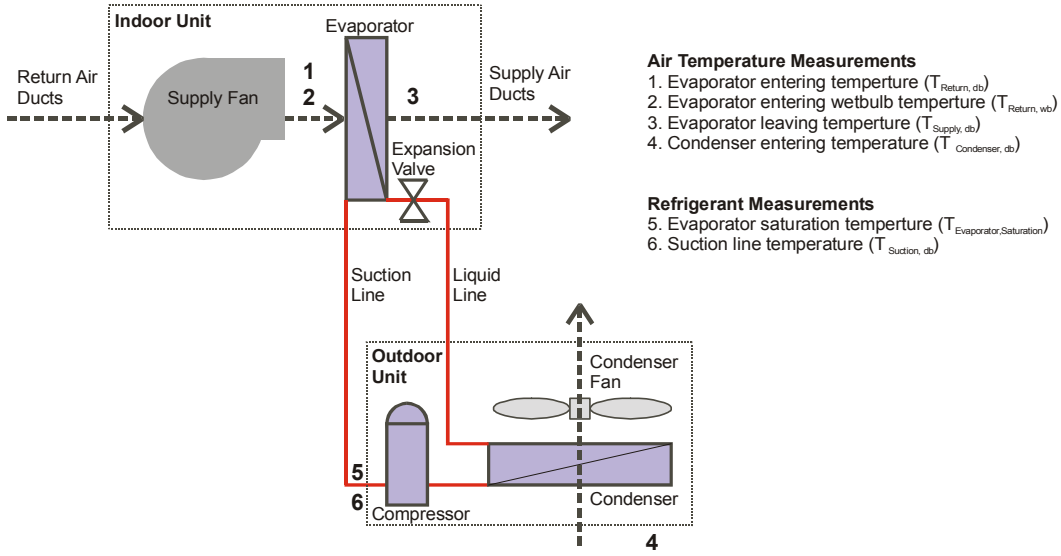
### 4.3.2 Standard Charge and Airflow Measurement Procedure

The first step is to turn on the air conditioning system and let it run for at least 15 minutes in order to stabilize temperatures and pressures. While the system is warming up and stabilizing, the HERS rater or the installer may fit the instruments needed to take the measurements.

Air temperatures are measured just before the air enters the cooling coil. For typical blow-through systems the measurement will be made in the fan cabinet between the fan and the coil. At this location (see points 1 and 2 in Figure 4-2), both the drybulb and wetbulb temperatures are measured. The air temperature is also measured in the supply duct, just down stream of the cooling coil (see point 3 in Figure 4-2). Finally the air temperature is measured where the air enters the outdoor condensing coil (see point 4 in Figure 4-2). It is important that the outdoor temperature sensor be shaded from direct sun.

In addition to the air temperature measurements, the HERS rater also takes two measurements for the refrigerant. Both of these measurements are taken near the suction line service valve near the compressor (see points 5 and 6 in Figure 4-2). The first measurement is the temperature of the refrigerant, which is taken by attaching a thermocouple to the outside of the refrigerant line. The second measurement is the saturation temperature of the refrigerant. The saturation temperature requires a special instrument called a refrigerant gauge that is installed to the suction line service valve (the inlet to the compressor). The saturation temperature is equivalent to measuring the saturation pressure, since there is a one-to-one relationship between the saturation temperature and the saturation pressure.

*Figure 4-2– Measurement Locations for Refrigerant Charge and Airflow Tests*




Once the temperatures are measured, the *Superheat Charging Method* is used to determine if the refrigerant charge is acceptable and the *Temperature Split Method* is used to determine if airflow across the evaporator coil is acceptable. The procedure may only be used when the outdoor temperature is 55°F or higher and after the HVAC installer has installed and charged the system in accordance with the manufacturer's specifications. The test must be performed by a certified HERS rater. The procedure requires properly calibrated digital thermometers, thermocouples, and a refrigerant gauge.

### *Superheat Charging Method*

The *Superheat Charging Method* involves comparing the measured superheat to a reference value from a table. The measured superheat is the difference between the temperature of the refrigerant ($T_{Suction, db}$) and the saturation temperature of the refrigerant ($T_{Evaporator, Saturation}$). The reference superheat is read from a table (see Table L-1 in Appendix L). For illustration purposes, the structure of the table is shown below as Table 4-1.

If the difference between the actual and target superheat is between minus 5 ºF and plus 5°F, then the system passes the required refrigerant charge criteria. If the difference is greater than plus 5°F, then the system is undercharged and the installer shall add refrigerant and repeat the measurement procedure. If the difference is between –5 and -100°F, then the system is overcharged and it is necessary for the installer to remove refrigerant and repeat the measurement procedure. Only an EPA certified technician may add or remove refrigerant.

*Table 4-1 – Structure of Target Superheat Temperature Table*

*Complete table is in Appendix L*

| | | Return Air Wet-Bulb Temperature (°F) ($T_{Return, wb}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 50 | 51 | 52 | 53 | 54 | 55 | .. | .. | 75 | 76 |
| Condenser Air Dry-Bulb Temperature (°F) ($T_{condenser, db}$) | 55 | Target Superheat Temperatures = (Suction Line Temperature minus Evaporator Saturation Temperature) – See Appendix L | | | | | | | | | |
| | 56 | | | | | | | | | | |
| | 57 | | | | | | | | | | |
| | .. | | | | | | | | | | |
| | .. | | | | | | | | | | |
| | 93 | | | | | | | | | | |
| | 94 | | | | | | | | | | |
| | 95 | | | | | | | | | | |

***The Temperature Split Method***

With the *Temperature Split Method,* the air temperature drop across the cooling coil is compared to a reference value read from a table. This temperature drop is called the temperature split, thus the name. The actual temperature split is the difference between the drybulb temperature in the return (entering the evaporator) and the drybulb temperature in the supply (leaving the evaporator). See the equation below.

*Equation 4-1*

$$\text{Actual Temperature Split} = T_{Return, db} - T_{Supply, db}$$

The Target Temperature Split depends on return air wet-bulb temperature ($T_{Return, wb}$) and return air dry-bulb temperature ($T_{Return, db}$). Table 4-2 shows the organization of the table. Appendix L has the full tables. If the difference between the actual and target is within plus 3°F and minus 3°F, then the system passes the airflow test.

If the difference is greater than plus 3°F, then airflow is inadequate and must be increased. Increasing airflow can be accomplished by eliminating restrictions in the duct system, increasing blower speed, cleaning filters, or opening registers. After the installer corrects the problem and verifies adequate airflow through the installers own testing, the HERS rater repeats the measurements to verify a correct refrigerant charge and airflow. The rater and/or the installer should allow system to stabilize for 15 minutes before performing the measurements.

If the difference is between minus 3 °F and minus 25 °F, the measurement procedure shall be repeated making sure that temperatures are measured at the center of the airflow. If the re-measured difference is still out of range, then (between minus 3 °F and minus 25 °F), the system passes, but it is likely that the air conditioner is not producing the capacity it was designed to produce. There may be problems with this air conditioner. (It is possible, but unlikely, that airflow is higher than average.)

*Table 4-2 – Structure of Target Temperature Split (Return Dry-Bulb minus Supply Dry-Bulb) Table*

*Complete table is in Appendix L*

| | | Return Air Wet-Bulb Temperature (°F) ($T_{Return, wb}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 50 | 51 | 52 | 53 | 54 | 55 | .. | .. | 75 | 76 |
| Return Air Dry–Bulb (°F) (T return, db) | 70 | Target Temperature Splits = (Return Dry Bulb Temperature minus Supply Dry Bulb Temperature) – See Appendix L | | | | | | | | | |
| | 71 | | | | | | | | | | |
| | 72 | | | | | | | | | | |
| | .. | | | | | | | | | | |
| | .. | | | | | | | | | | |
| | 82 | | | | | | | | | | |
| | 83 | | | | | | | | | | |
| | 84 | | | | | | | | | | |

### 4.3.3 Alternate Charge and Airflow Measurement Procedure

This section describes the Alternate Charge and Airflow Measurement Procedure. With this method, the required refrigerant charge is calculated using the *Weigh-In Charging Method* and adequate airflow across the evaporator coil is calculated using the *Measured Airflow Method*. This method is used when the outdoor temperature is below 55°F. EPA certified technicians, not HERS raters, must perform the procedure. The technician that performs this procedure must be able to do the following:

- Transfer and recover refrigerant
- Accurately weigh the amount of refrigerant added or removed using an electronic scale
- Calculate the refrigerant charge adjustment needed to compensate for non-standard dimensions in the suction line or liquid line

The airflow across the indoor evaporator coil shall be measured using one of the two methods described in Appendix J:

- Section 4.3.7.2.1 Diagnostic Fan Flow Using Flow Hood
- Section 4.3.7.2.2 Diagnostic Fan Flow Using Plenum Pressure Matching

The measured airflow method is compared to see that it is above the required minimum of 385 cfm per nominal ton of capacity (assuming coil is dry). The following steps describe the calculations using the measurement procedure described in Appendix J.

1. Record the measured air flow (cfm measured) obtained from the measurement procedures described in Appendix J of the Residential Manual.
2. Obtain and record the rated cooling capacity ($C_{cooling}$) in Btu/h.
3. Calculate the minimum airflow in cfm as $C_{cooling}$ X 0.032.
4. If the measured airflow is greater than the required airflow, then the system passes the adequate airflow criteria. If the measured airflow is less than the required airflow, the system does not pass the adequate airflow criteria.

# 4.4 Diagnostics and Field Verification

This section describes the procedures for special verification of energy efficiency measures and for diagnostic testing of air distribution ducts, building envelope leakage, refrigerant charge and airflow by a certified HERS rater. Diagnostic testing and/or field verification by a HERS rater is often required to show compliance with both the prescriptive and performance compliance methods. However, field verification and testing is only required when measures or equipment are installed which require field verification and/or testing, as specified in Section 4.4.2. If these types of measures or equipment are not installed, then field verification and testing is not required. For example, if there are no air distribution ducts (no new ducts for additions), then no testing of ducts is required. Similarly, if there is no split system air conditioner or heat pump, then it is not necessary to diagnostically test the refrigerant charge and airflow. See “When a HERS Rater is Not Needed” in Section 3.1 for a discussion of testing and verification requirements with the prescriptive standards. See sections 5.4.6, 5.4.8 and 5.4.9 for a discussion of testing and verification requirements with the performance approach.

### 4.4.1 California Home Energy Rating Systems

The Commission is required to regulate home energy rating system (HERS) providers in California. These regulations appear in the California Code of Regulations, Title 20, Chapter 4, Article 8, Sections 1670-1675. Approved HERS providers are authorized to certify raters and maintain quality control over ratings. Ratings are based on visual inspection and diagnostic testing of the physical characteristics and energy efficiency features of dwelling units, as constructed. When the term "dwelling unit" is used in reference to Home Energy Rating Systems (HERS) Required Verification and Diagnostic Testing applied to multifamily buildings, it shall mean each dwelling unit within each multifamily building project. When the term "building owner" is used in this Chapter, it shall mean owner of the dwelling unit.

When compliance documentation indicates field verification and diagnostic testing of specific energy efficiency measures as a condition for complying with Title 24, an approved HERS provider and certified HERS rater shall be used to conduct the field verification and diagnostic testing. HERS providers and raters shall be considered special inspectors by building departments, and shall demonstrate competence, to the satisfaction of the building official, for the visual inspections and diagnostic testing. The HERS provider and rater shall be independent entities from the builder or subcontractor installer of the energy efficiency improvements being tested and verified, and shall have no financial interest in the installation of the improvements. HERS raters cannot be employees of the builder or contractor whose work they are verifying. Also HERS raters cannot have financial interest in the builder's or contractor's business or advocate or recommend the use of any product or service that they are verifying.

*Example 4-1 – HERS Rater Conflict of Interest*

***Question***

I heard that there are conflict-of-interest requirements that HERS raters must abide by when doing field verification and diagnostic testing. What are these requirements?

***Answer***

HERS raters are expected to be objective, independent, third parties when they are fulfilling their duties as field verifiers and diagnostic testers. In this role they are serving as special inspectors for local building departments. By law HERS raters must be independent entities from the builder or subcontractor installer of the energy efficiency features being tested and verified. They can have no financial interest in the installation of the improvements. HERS raters can not be employees of the builder or subcontractor whose work they are verifying. Also, HERS raters can not have financial interest in the builder's or contractor's business or advocate or recommend the use of any product or service that they are verifying. Section 106.3.5 of the California Building Code prohibits a special inspector from being employed (by contract or other means) by the contractor who performed the work that is being inspected.

The Commission expects HERS raters to enter into a contract with the builder (not with sub-contractors) to provide independent, third party diagnostic testing and field verification, and the procedures adopted by the Commission call for direct reporting of results to the builder, the HERS provider and the building official. Although the Commission does not recommend it, a "three party contract" with the builder is possible, provided that the contract delineates both the independent responsibilities of the HERS rater and the responsibilities of a sub-contractor to take corrective action in response to deficiencies that are found by the HERS rater. Such a "three party contract" may also establish a role for a sub-contractor to serve as contract administrator for the contract, including scheduling the HERS rater, invoicing and payment provided the contract ensures that monies paid by the builder to the HERS rater can be traced through audit. It is critical that such a "three party contract" preserves rater independence in carrying out the responsibilities specified in Commission adopted field verification procedures. Even though such a "three party contract" is not on its face in violation of the requirements of

the Commission, the closer the working relationship between the HERS rater and the sub-contractor whose work is being inspected, the greater the potential for compromising the independence of the HERS rater.

The California Home Energy Efficiency Rating System (CHEERS) has been approved by the Commission to serve as the HERS provider to certify and oversee HERS raters throughout the State. CHEERS is required to provide ongoing monitoring of the propriety and accuracy of HERS raters in the performance of their duties and to respond to complaints about HERS rater performance. In cases where there may be real or perceived compromising of HERS rater independence, CHEERS is responsible for providing increased scrutiny of the HERS rater, and taking action to ensure objective, accurate reporting of diagnostic testing and field verification results, in compliance with Commission adopted procedures.

Building officials have authority to require HERS raters to demonstrate competence, to the satisfaction of the building official. Building officials should place extra scrutiny on situations where there may be either real or perceived compromising of the independence of the HERS rater, and exercise their authority to disallow a particular HERS rater from being used in their jurisdiction or disallow HERS rater practices that the building official believes will result in compromising of HERS rater independence.

### 4.4.2 HERS Required Verification and Diagnostic Testing

HERS diagnostic testing and field verification is required for:

- Duct air sealing,
- ACCA Manual D design and installation,
- Refrigerant charge and airflow measurement, and
- Building envelope sealing beyond improvements covered by default assumptions,

HERS field verification is required for:

- Thermostatic expansion valves,
- Duct surface area reductions, and
- Duct location improvements beyond those covered by default assumptions.

These features shall be listed as *HERS Verification Required* features on the *Certificate of Compliance* (CF-1R) and the *Computer Method Summary* (C-2R). Such verification constitutes “eligibility and installation criteria” for these features. Field verified and diagnostically tested features must be described in the *Compliance Supplement*.

### 4.4.3 Installation Certification

When compliance includes duct sealing, ACCA Manual D design and installation, refrigerant charge and airflow measurement or envelope sealing, builder employees or subcontractors shall:

- Complete diagnostic testing, and
- Certify on the CF-6R the diagnostic test results and that the work meets the requirements for compliance credit.

For refrigerant charge and airflow measurement when the outside temperature is below 55°F, the installer shall follow the alternate charge and airflow measurement procedure described in Appendix L, Section 3. Builder employees or subcontractors using these

procedures shall certify on the CF-6R that they used these procedures, the diagnostic results, that the work meets the requirements for compliance credit, and that they will return to correct refrigerant charge and airflow if the HERS rater determines at a later time when the outside temperature is above 55°F that correction is necessary.

For duct sealing completed at the rough-in stage of construction using aerosol sealant closures, builder employees or subcontractors shall:

- At rough-in, complete the fan pressurization test and certify on the CF-6R the diagnostic results,
- After installation of the interior finishing wall, verify sealing of the ducts using either the house pressure test or the pressure pan test or by visual inspection of all duct connections (including duct to air handler connections), and
- Certify on the CF-6R the diagnostic results and that the work meets the requirements for compliance credit.

When compliance includes a thermostatic expansion valve, duct surface area reductions and duct location improvements beyond those covered by default assumptions, builder employees or subcontractors shall:

- Record the feature on the CF-6R,
- Record on the CF-6R the duct surface area in each duct location, and
- Certify on the CF-6R that the duct surface area and locations match those on the plans, and that the work meets the requirements for compliance credit.

Installation certifications are required for each and every dwelling unit.

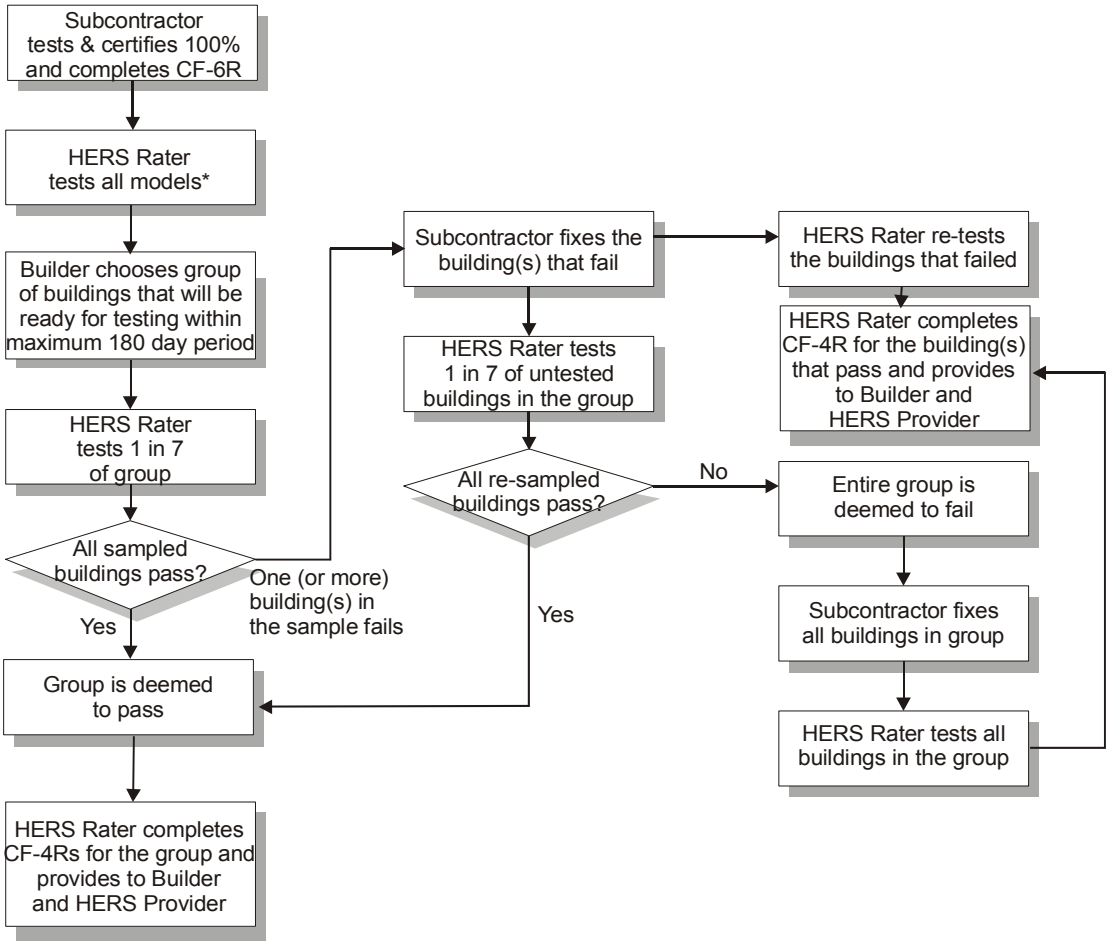
### 4.4.4 HERS Verification Procedures

At the builder's option HERS field verification and diagnostic testing shall be completed either for each dwelling unit or for a sample of dwelling units. Dwelling units in the sample shall be in the same subdivision or multifamily housing development. Field verification and diagnostic testing for compliance credit for duct sealing shall use the diagnostic duct leakage from fan pressurization of ducts in Section 4.3.8.2.1 of Appendix J.

Note that the test (HERS field verification and diagnostic testing for duct sealing compliance credit) must take place with all registers, grilles and supply air diffusers installed.

*Figure 4-3 – Simplified Flowchart of the Sampling Process for Diagnostic Testing by a HERS Rater*

*See Section 4.4.4 for procedural details and Section 4.4.5 for responsibilities and documentation requirements*




* Builder may choose to have HERS Rater test 100% of buildings, in which case sampling does not apply.

Field verification and diagnostic testing for compliance credit for refrigerant charge and airflow measurement shall use the standard charge and airflow measurement procedure specified in Appendix L. Field verification and diagnostic testing shall not use the alternate charge and airflow measurement procedure. Field verification and diagnostic testing for refrigerant charge and airflow measurement shall be scheduled and completed when the outside temperature is above 55°F.

The builder shall provide the HERS provider a copy of the CF-6R containing the installation certifications required in Section 4.4.3. Prior to completing field verification and diagnostic testing, the HERS rater shall first verify that the installation certifications have been completed.

If the builder chooses the sampling option, the procedures described in this section shall be followed. For multifamily buildings, also see Section 8.1. Figure 4-3 is a simplified flowchart of the sampling process. The reader is cautioned not to rely solely on Figure 4-3, and to be aware of the procedures described in Section 4.4.4 and the Responsibilities and Documentation requirements in Section 4.4.5.

***Initial Field Verification and Testing***

The HERS rater shall diagnostically test and field verify the first dwelling unit of each model. To be considered the same model, dwelling units shall be in the same subdivision or multifamily housing development and have the same energy designs and features, including the same floor area and volume, for each dwelling unit, as shown on the CF-1R. This initial testing allows the builder to identify and correct any potential construction

flaws or practices in the build out of each model. If field verification and diagnostic testing determine that the requirements for compliance are met, the HERS rater shall provide a signed and dated *Certificate of Field Verification and Diagnostic Testing* (CF-4R) to the builder and the HERS provider

***Sample Field Verification and Testing***

After the initial testing is completed, the builder shall identify a group of dwelling units from which a sample will be selected for testing, and notify the HERS provider. For multifamily buildings, see Section 8.1. The group shall include only dwelling units expected to be ready for diagnostic testing within a maximum 180-day period.

The builder shall identify the group of dwelling units by location of County, City and either the street address or the subdivision and lot number, or the multifamily housing project name and shall identify the names and license numbers of subcontractors responsible for the duct installation, duct sealing, thermostatic expansion valve installation, refrigerant charge and airflow measurement or envelope sealing that requires diagnostic testing or field verification. The builder may add additional dwelling units to the group by notifying the HERS provider as long as they are completed within the maximum 180-day period.

The HERS rater shall select a minimum of one out of every seven sequentially completed dwelling units from the group, rounded up to the next whole number, for diagnostic testing and field verification. When several dwelling units are ready for testing at the same time, the HERS rater shall randomly select the dwelling units to be tested. The HERS rater shall diagnostically test and field verify the dwelling units selected by the HERS rater.

If field verification and diagnostic testing determines that the requirements for compliance are met, the HERS rater shall provide a signed and dated *Certificate of Field Verification and Diagnostic Testing* to the builder and the HERS provider. The *Certificate of Field Verification and Diagnostic Testing* shall report the successful diagnostic testing results and conclusions regarding compliance for the tested dwelling unit.

The HERS rater shall also provide a signed and dated *Certificate of Field Verification and Diagnostic Testing* to the builder and the HERS provider for up to six additional dwelling units from the group. The *Certificate* shall not be provided for dwelling units in which the feature requiring field verification and diagnostic testing has not been installed, sealed or completed.

The maximum 180-day period shall begin on the date of the first *Certificate of Field Verification and Diagnostic Testing* for the group and shall end either with the date of the last verified test from the group or 180 days, whichever is less. Once all homes in the group have been certified, the 180-day clock is reset. Dwelling units within the group for which a *Certificate of Field Verification and Diagnostic Testing* has not been completed within 180 days from the date of the first *Certificate of Field Verification and Diagnostic Testing* for the group, as determined by the HERS provider, shall either be individually tested or be included in a group of dwelling units in a subsequent sample period.

Whenever the builder changes subcontractors who are responsible for the feature that is being diagnostically field verified and tested, the builder shall notify the HERS rater of any subcontractors who have changed, and terminate sampling for the identified group. All dwelling units using *HERS Required Verification* features for compliance that were installed by previous subcontractors or were subject to verification and testing under the supervision of a previous HERS provider, for which the builder does not have a completed *Certificate of Field Verification and Diagnostic Testing*, shall either be individually tested or included in a separate group for sampling. Dwelling units with installations completed by new subcontractors shall either be individually tested or shall be included in a new sampling group following a new *Initial Field Verification and Testing*.

The HERS rater shall not notify the builder when sample testing will occur prior to the completion of the work that is to be tested. After the HERS rater notifies the builder when testing will occur, the builder shall not do additional work on the features being tested.

***Re-sampling, Full Testing and Corrective Action,***

When a failure is encountered during sample testing, the HERS rater shall conduct re-sampling to assess whether that failure is unique or the rest of the dwelling units are likely to have similar failings. The HERS provider shall select for re-sampling one out of every seven of all of the untested dwelling units in the group, rounded up to the next whole number.

If testing in all dwelling units in the re-sample confirms that the requirements for compliance credit are met, then the dwelling unit with the failure shall not be considered an indication of failure in the other dwelling units in the group. The builder shall take corrective action for the dwelling unit with the failure, and then the HERS rater shall retest to verify compliance and issue a signed and dated *Certificate of Field Verification and Diagnostic Testing* to the builder. Sampling shall then resume for the remainder of the group.

If field verification and testing in any of the dwelling units in the re-sample results in a second failure, the builder shall take corrective action in all unoccupied dwelling units in the group that have not been tested but for which a *Certificate of Field Verification and Diagnostic Testing* has been completed. The HERS rater shall conduct field verification and diagnostic testing in each of these dwelling units to verify that problems have been corrected and that the requirements for compliance have been met, and shall report to the HERS provider.

Builders shall offer at no charge to building owners in occupied dwelling units in the group to complete field verification and testing and corrective action if necessary. Building owners may decline this offer. Builders shall report the identifying location of any dwelling unit in which the building owner declines field verification and testing and corrective action to the HERS provider. The HERS provider shall verify that the builder has made this offer. If a building owner in an occupied dwelling unit declines this offer, field verification, testing and corrective action will not be required for that dwelling unit and the dwelling unit will no longer be considered a part of the group. If a building owner accepts this offer, the builder shall take corrective action. The HERS rater shall then conduct field verification and diagnostic testing to verify that problems have been corrected and that the requirements for compliance have been met, and shall report to the HERS provider.

The HERS provider shall file a report with the building department explaining all action taken (including field verification, testing, corrective action, offers to building owners for testing and corrective action and building owner declines of such offers) to bring into compliance dwelling units for which a signed and dated *Certificate of Field Verification and Diagnostic Testing* has been provided to the builder. If corrective action requires work not specifically exempted by Section 112 of the CMC or Section 106 of the UBC, the builder shall obtain a permit from the building department prior to commencement of any of the work.

Until corrections, field verification and testing of all dwelling units in the group have been completed or building owners in occupied dwelling units have declined corrective action, sampling of additional dwelling units in the group shall cease. If additional dwelling units in the group are completed during the time required to correct, field verify and test the previously completed dwelling units in the group, the rater shall individually field verify and diagnostically test those additional dwelling units to confirm that the requirements for compliance credit are met. Once corrections, field verification and testing is completed for all dwelling units that have a *Certificate of Field Verification and Diagnostic Testing*, excepting those where building owners have declined corrective action, the builder shall either resume sampling for the remainder of the dwelling units in the group or terminate the group.

Corrections shall not be made to a sampled dwelling unit to avoid a failure. If corrections are made to a sampled dwelling unit, corrections, field verification and testing shall be performed on 100% of the dwelling units in the group.

### 4.4.5 Responsibilities and Documentation

***Builder Responsibilities***

Builder employees or subcontractors responsible for completing either diagnostic testing, visual inspection or verification as specified in Section 4.4.3 shall certify the diagnostic testing results and that the work meets the requirements for compliance credit on the CF-6R.

The builder shall provide the HERS provider with the identifying location of the group of dwelling units to be included in the sample for field verification and diagnostic testing and the expected date that sampling may begin. The builder shall provide the HERS provider a copy of the CF-6R signed by the builder employees or sub-contractors certifying that diagnostic testing and installation meet the requirements for compliance credit.

The builder shall provide a *Certificate of Field Verification and Diagnostic Testing* signed and dated by the HERS rater to the building official in conjunction with requests for final inspection for each dwelling unit.

When resampling reveals a failure, builders shall offer at no charge to building owners in occupied dwelling units in the group to complete field verification, testing and corrective action if necessary. Building owners may decline to have field verification and testing and corrective action completed. Builders shall report the identifying location of any dwelling unit in which the building owner declines field verification and testing and corrective action to the HERS provider. Builders shall take corrective action as required in all unoccupied dwelling units in the group and in occupied dwelling units in the group where building owners have accepted field verification, testing and corrective action.

***HERS Provider and Rater***

The HERS provider shall maintain a list of the dwelling units in the group from which sampling is drawn, the dwelling units selected for sampling, the dwelling units sampled and the results of the sampling, the dwelling units selected for re-sampling, the dwelling units that have been tested and verified as a result of re-sampling, the corrective action taken, and copies of all *Certificates of Field Verification and Diagnostic Testing* for a period of five years.

The HERS rater providing the diagnostic testing and verification shall sign and date a *Certificate of Field Verification and Diagnostic Testing* certifying that he/she has verified that the requirements for compliance credit have been met. *Certificates of Field Verification and Diagnostic Testing* shall be provided for the tested dwelling unit and each of up to six other dwelling units from the group for which compliance is verified based on the results of the sample. The HERS rater shall provide this certificate to the builder and the HERS provider.

The HERS rater shall provide a separate *Certificate of Field Verification and Diagnostic Testing* for each dwelling unit the rater determines has met the diagnostic requirements for compliance. The HERS rater shall identify on the *Certificate of Field Verification and Diagnostic Testing* if the dwelling unit has been tested or if it was an untested dwelling unit approved as part of sample testing. The HERS rater shall not sign a *Certificate of Field Verification and Diagnostic Testing* for a dwelling unit that does not have a CF-6R signed by the installer as required in Sections 4.4.3.

If field verification and testing on a sampled dwelling unit identifies a failure to meet the requirements for compliance credit, the HERS rater shall report to the HERS provider and the builder that re-sampling will be required.

If re-sampling identifies another failure, the HERS rater shall report to the HERS provider and the builder that corrective action and diagnostic testing and field verification will be required for all the untested dwelling units in the group. This report shall specify the identifying location of all dwelling units that must be corrected and fully tested.

The HERS provider shall also report to the builder once diagnostic testing and field verification has shown that the failures have been corrected in all of the dwelling units

except those for which the building owner has declined field verification, testing and corrective action.

When individual dwelling unit testing and verification confirms that the requirements for compliance have been met, the HERS rater shall provide a *Certificate of Field Verification and Diagnostic Testing* for each previously untested/unverified dwelling unit in the group and for each additional dwelling unit of the same model completed during the time required to correct, verify and test the previously untested/unverified dwelling units in the group.

The HERS provider shall file a report with the building department explaining all action taken (including field verification, testing, corrective actions, offers to building owners for testing and corrective action, and building owner declines of such offers) to bring into compliance dwelling units for which a signed and dated *Certificate of Field Verification and Diagnostic Testing* has been provided to the builder.

***Building Department***

The building department at its discretion may require independent testing and field verification in conjunction with the building department's required inspections, and/or observe the diagnostic testing and field verification performed by builder employees or subcontractors and the certified HERS rater in conjunction with the building department's required inspections to corroborate the results documented in installer certifications, and in the *Certificate of Field Verification and Diagnostic Testing*.

For dwelling units that have used a compliance alternative that requires field verification and diagnostic testing, the building department shall not approve a dwelling unit for occupancy until the building department has received from the builder a *Certificate of Field Verification and Diagnostic Testing* that has been signed and dated by the HERS rater.

If necessary to avoid delay of approval of dwelling units completed when outside temperatures are below 55°F, building departments may approve compliance credit for refrigerant charge and airflow measurement when installers have used the alternate charging and airflow measurement procedure described in Appendix L, Section 3. This approval will be on the condition that installers provide a signed agreement (CF-6R) to the builder with a copy to the building department to return to correct refrigerant charge and airflow if the HERS rater determines at a later time when the outside temperature is above 55°F that correction is necessary.

## 4.5 Procedures for HVAC System Design and Installation

The *Standards* have prescriptive and mandatory requirements for duct system design, sealing and installation. A truly quality duct system requires attention to all aspects of duct design, sealing and installation, and performance testing to assure that the system actually delivers comfort to all portions of the home in an energy efficient manner. Incremental improvement, for example through duct sealing alone, may not result in a well performing duct system.

The *Procedures For HVAC System Design and Installation* specified in Appendix K are intended to produce duct systems that are well designed, installed and performance tested to verify their effectiveness in delivering comfort and energy efficiency to home occupants. These procedures comprehensively address all aspects of quality installation of HVAC equipment and duct systems. The Commission highly recommends that builders insure that all aspects of the *Procedures For HVAC System Design and Installation* given in Appendix K are followed.